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## VOLUME 4. AIRCRAFT EQUIPMENT AND OPERATIONAL AUTHORIZATIONS

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### CHAPTER 1. AIR NAVIGATION, COMMUNICATIONS, AND SURVEILLANCE

#### SECTION 2. AIR NAVIGATION APPROVAL REQUIREMENTS

**31. GENERAL.** This section contains direction and guidance to be used by certification teams and inspectors when approving operator requests for air navigation operations. Inspectors approve these operations by issuing appropriate operations specifications (OpSpecs) paragraphs in part B of OpSpecs. Except for Class I navigation, the approval process normally requires validation testing. The five phases of the validation process are described in volume 3, chapter 9, section 2. Volume 3, chapter 9, section 8 contains a detailed discussion of validation testing requirements. This section provides additional guidance specifically related to air navigation requirements.

**33. SUBJECT FAMILIARIZATION AND APPROVAL REQUIREMENTS.** Once an operator has requested approval for air navigation operations, it is essential that inspectors fully understand the concepts, national policies, standard practices, direction, and guidance related to the area of proposed operations. In addition, FAA navigation technical specialists are available to assist principal inspectors in understanding, evaluating, and approving air navigation operations.

A. Section 1 and subsequent sections of this chapter contain much of this information and additional references for more detailed information and guidance.

B. When processing initial requests for any air navigation operations involving class II navigation, certification teams and principal inspectors *must* request guidance from a navigation specialist. Certification teams and principal inspectors *must* also request guidance from a navigation specialist for any operations involving “special areas of operation (e.g., Reduced Vertical Separation Minimum (RVSM), Required Navigation Performance (RNP), Minimum Navigation Performance Specification (MNPS), West Atlantic Route System (WATRS), etc.).” Certification teams and principal inspectors *must* request guidance from a navigation specialist at one of the following locations:

- The San Francisco (SFO) International Field Office (IFO)
- The operations section of AFS-400 (HQ).

#### **35. DETERMINING THE CLASS OF NAVIGATION.**

The first determination that must be made concerning an air navigation approval request is the category of operation proposed. The inspector must determine whether the proposed operation is Class I navigation, Class II navigation, or both. The decisive factor in this determination is the operational service volume of the International Civil Aviation Organization (ICAO) standard ground-based navigational aids (NAVAID) within the proposed area of operation. If the minimum en route flight altitudes specified and the locations of the ICAO standard ground-based NAVAIDs ensure that the flight will always be within the operational service volume, the entire en route operation is Class I navigation. In situations where the entire area of operation (at the minimum flight altitude specified) is outside (beyond) the operational coverage volume of ICAO standard ground-based NAVAIDs, the operation is Class II navigation. When portions of the proposed area of operation ensure that flights are continuously within the operational service volumes of ICAO standard ground-based NAVAIDs, that portion of the flight is Class I navigation and the remaining portion is Class II navigation (see sections 3 and 4 of this chapter for in-depth discussions of Class I and Class II navigation). The Global Positioning System (GPS) has been accepted by ICAO as a standard NAVAID. However, a distinction is made between standard ground-based NAVAIDs and standard NAVAIDS.” Standard ground-based NAVAIDs have an operational service volume and standard NAVAIDS do not. The National Airspace Systems (NAS) of ICAO contracting member states are based on the operational service volume of these ground-based facilities but GPS, by virtue of its universal signal coverage, is not restricted to an operational service volume. Navigational performance within the operational service volume and Air Traffic Control (ATC) separation minimums can be predicated on the use of both ICAO standard ground NAVAIDs and ICAO standard NAVAIDS.

A. *Flight Altitude.* It is important to understand that the minimum flight altitude is a key factor in the determination of the category of navigation (Class I or Class II). The operational service volume of a particular standard ground-based NAVAID is heavily influenced by flight altitude. For example, at high altitude (above flight level (FL) 180), most

VHF Omnidirectional Range Stations (VOR) published for use at these altitudes have an operational service volume that extends to a radius of at least 130 nautical miles (nm) from the facility. However, at low altitudes (below 10,000 feet MSL), the operational service volume of many VORs seldom exceeds 40 nm. Therefore, it is highly probable that for a route length of 260 nm between VORs, operations above FL 180 would be Class I navigation and operations conducted below 10,000 feet MSL would include both Class I and Class II navigation. The Class II navigation portion would begin at the edge of the operational service volume of the first VOR and end at the edge of the operational service volume of the second VOR. If the inspector determines that the proposal only involves Class I navigation, the direction and guidance in section 3 of this chapter will be used. If the proposal involves both Class I and Class II navigation, the direction and guidance in sections 3 and 4 of this chapter will be used for evaluation and approval or denial of the proposal.

**NOTE: Refer to the Aeronautical Information Manual (AIM) for a more extensive discussion of operational service volume.**

*B. Range of Standard Ground-Based NAVAIDs.* Generally, determination of the exact range (operational service volume) of the ground-based NAVAIDs intended to be used is not necessary. For example, a flight departing from the continental U.S. with a destination in Europe would obviously perform Class I and Class II navigation and require equipment appropriate for both. In other situations, it can be readily determined that flight operations will be conducted entirely within the operational service volume of standard ground-based NAVAIDs. However, sometimes a determination of the exact range of a NAVAID is required to evaluate compliance with the requirement for a reliable fix once each hour. In the U.S., the frequency management branch (of Airways Facilities) in each region may be contacted to determine if a particular NAVAID has been flight checked to a range greater than standard.

*C. Foreign/Remote Operations.* In foreign countries and in oceanic/remote areas, this determination is more complex. In these cases, the determination is based on an equivalence to U.S. standards. In general, VOR, VOR/distance measuring equipment (DME) routes and fixes published in those areas are within the operational service volume (or foreign equivalent) of the ground-based NAVAIDs specified. However, most Air Traffic Service (ATS) routes based on nondirectional beacons (NDB) in oceanic/remote areas are Class II navigation over a considerable portion of the route. For example, the standard service volume (or coverage) of high powered NDBs seldom exceeds 75 nm. In special cases, a few NDBs have been evaluated by flight inspection and have an officially designated extended service volume significantly greater than 75 nm. National/Regional Aeronautical Information Publications (AIP) and foreign flight inspection offices are

the best and most up to date sources of information on the operational service volume of these NAVAIDs.

**37. SPECIAL OPERATIONS.** After determining whether a particular operation is Class I navigation, Class II navigation, or a combination of both, another important step is to determine if the operation involves any specific navigation authorizations to operate into special areas of operation or to use equipment or special navigation techniques.

A. Examples of special areas of operation include the following:

- Areas of Magnetic Unreliability (AMU)
- Polar operations
- North Atlantic Minimum Navigation Performance Specification (NAT/MNPS) airspace
- Canadian MNPS airspace
- Central East Pacific (CEP) airspace
- North Pacific (NOPAC) airspace
- Pacific Organized Track System (PACOTS)
- Restricted international areas
- Arctic Ocean or Antarctic Ocean
- West Atlantic Route System (WATRS) and the Caribbean Sea
- South Atlantic (Atlantic routes)
- Gulf of Mexico control areas (Gulf routes)
- Reduced Vertical Separation (RVSM)
- Required Navigation Performance (RNP)-x (x is the value in nautical miles associated with an airspace or route that requires a specific RNP)

B. Examples of special navigation equipment include the following:

- Private (non-federal) NAVAIDs or broadcast stations (14 CFR part 171, Nonfederal Navigation Facilities)
- Area Navigation (RNAV)
- Loran-C
- Inertial Navigation Systems (INS) and Inertial Reference Systems (IRS)
- GPS

C. Methods of special navigation include the following:

- Pilotage
- Use of a flight navigator
- Celestial
- Free gyro or grid

### **39. NAVIGATION EQUIPMENT.**

A. In all cases, it is necessary for the operator to provide

written aircraft eligibility documentation that explicitly states that the aircraft is properly certificated, equipped, and maintained to perform the required functions for the specific type of navigation and other requirements related to any special operation (referred to in paragraph 37 above).

(1) The written evidence may take the form of a type certificate (TC), supplemental type certificate (STC), Aircraft Flight Manual (AFM), AFM Supplement (AFMS), or Flight Standards Board (FSB) Report. In certain cases involving special areas of operation, such as AMU, RNP airspace, RVSM, and NAT/MNPS, the airworthiness approval must reflect that these special requirements are also met.

(2) The eligible aircraft must have equipment where the aircraft documentation explicitly states that the installation has received airworthiness approval for the type of operations in accordance with a Field Approval (FAA Form 337, Major Repair and Alteration (Airframe, Powerplant, Propeller, or Appliance)), Advisory Circular (AC), or other applicable documentation.

(3) This determination must be coordinated closely with the principal avionics inspector (PAI) or the regional Flight Standards Airworthiness branch. It is FAA policy and guidance that the principal inspectors shall coordinate with one of the FAA navigation specialists (see paragraph 33 of this section). If the certificate holder or operator is not able to provide the principal inspectors with specific eligibility from the AFM, AFMS, or the FSB Report, official written equipment eligibility must be attained.

(4) If the FSDO is unable to determine equipment eligibility from the approved documentation, it should forward the request and supporting data through its FAA Flight Standards Regional Division to the appropriate Aircraft Evaluation Group (AEG). The AEG will verify that the aircraft and equipment meet the criteria for the specific operations and that the system can safely fly the specified operation. The AEG will provide written documentation (e.g., amend FSB Report or other official documentation) to verify the eligibility of that equipment.

*B. Conventional Navigation Equipment.* In the case of Class I navigation with conventional navigation equipment, such as VOR, VOR/DME, NDB, a statement in the FAA-approved AFM or STC that the navigation system and/or equipment is approved for instrument flight rules (IFR) flight is usually sufficient. For Class I navigation with other types of RNAV equipment, the equipment must be certified for IFR operations and installed and maintained in accordance with the FAA-approved documentation appropriate for that specific RNAV equipment.

*C. Area Navigation (RNAV).* RNAV provides enhanced navigational capability. RNAV equipment can automatically compute the airplane position, actual track, and ground speed and then provide meaningful information relative to a

route of flight selected by the pilot. Typical equipment will provide the distance, time, bearing, and crosstrack error relative to the selected “TO” or “active” waypoint and the selected route. Several RNAV systems with different navigational performance characteristics are capable of providing area navigational functions. Present day RNAV equipment is considered to be equipment that operates by automatically determining aircraft position from one or a combination of the following sensors with the means to establish and follow a desired path:

- VOR/DME
- DME/DME
- INS. INS must be approved under the provision of 14 CFR part 121, section 121.355 and Appendix G. This approval is not specifically required for 14 CFR part 135, but the same approval criteria apply.
- Loran-C. Loran-C systems must be approved for the area of operation under the provisions of AC 20-121, Airworthiness Approval of Airborne Loran-C Navigation Systems for Use in the U.S. National Airspace System (NAS), (or equivalent). See AC 90-92, Guidelines for the Operational Use of Loran-C Navigation Systems Outside the U.S. National Airspace System (NAS).
- GPS systems. GPS systems must be approved in accordance with Technical Standard Order (TSO) C-129, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS), TSO C-145, Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS), or TSO C-146, Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS), and other installation criteria or AC 20-130 (as amended), Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, AC 20-138 (as amended), Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System, and AC 90-94 (as amended), Guidelines for Using GPS Equipment for IFR En Route and Terminal Operations and for Nonprecision Instrument Approaches in the U.S. National Airspace System, as applicable.
- Modern multi-sensor systems (such as IRS/FMS) can integrate one or more of the above sensors to provide a more accurate and reliable navigational system (see AC 20-130 and AC 25-15, Approval of Flight Management Systems in Transport Category Airplanes).

(1) RNAV systems used for VFR operations (Class I and/or Class II) must reflect an approval for VFR use. RNAV systems used for IFR Class I navigation (except operations in the U.S. Class A airspace) and Class II navigation must reflect a statement that the system meets the reliability and performance criteria, that the system is approved for IFR flight, and if required, approved for any special areas of operation in accordance with the following ACs, as applicable:

- AC 20-130 (as amended),
- AC 20-121 (as amended), Airworthiness Approval of Airborne Loran-C Navigation Systems for Use in the U.S. National Airspace System (NAS)
- AC 20-138 (as amended),
- AC 25-4, (as amended), Inertial Navigation Systems
- AC 25-15 (as amended)
- AC 90-94 (as amended)
- Technical Standard Order (TSO) C-129
- TSO C-145a
- TSO C-146a

**41. TRAINING PROGRAMS AND MANUALS.** Other important areas that must be considered are approved/accepted training programs and approved/accepted company manuals for the equipment used. The training programs and company manuals must adequately address the special characteristics of the proposed area of operation and the operational (navigation) practices and procedures that must be used. Other sections of this chapter provide additional direction and guidance on some specific requirements for training programs and company manuals for the various navigation systems and/or areas of operation.

**43. MINIMUM EQUIPMENT LISTS (MEL).** Additionally, most approvals of navigation equipment and/or areas of operation new to a particular operator also require changes to the company MEL. In all cases, principal inspectors must review the company MEL to ensure that complete and accurate direction and guidance are provided to company personnel. (See Order 8400.10, volume 4, chapter 4.)

**45. NAVIGATION PRACTICES, TECHNIQUES, AND PROCEDURES.** Navigation practices, techniques, and procedures are other important parts of the approval process. They are especially significant in long range navigation systems and in operations using RNAV systems. The approval of these operations almost always necessitates changes in cockpit checklists and operating practices and procedures. Due to the complexity of these operations, the necessary changes must be determined on a case-by-case basis considering the operator, the equipment, and the area of operations.

**47. VALIDATION TESTING REQUIREMENTS.** It is essential for the inspector to evaluate the need for validation testing. In a simple case, such as approving Class I navigation in additional areas within the U.S. using conventional VOR/DME systems, a validation test is not necessary. However, in more complex cases, validation testing is essential to demonstrate the operator's capability and competence to safely conduct the proposed operation (see volume 3, chapter 9, section 8) (see paragraph 31).

**49. GUIDANCE FOR USE OF AIRCRAFT EQUIPMENT SUFFIXES.** For guidance in the use of aircraft equipment suffixes, refer to the Aeronautical Information Manual or the ATC handbook, Order 7110.65. Any comments or inquiries concerning the criteria and guidance to qualify and use the equipment suffix should be directed to the Flight Technologies and Procedures Division, AFS-400 (HQ).

## **51. FAA APPROVAL OF GLOBAL POSITIONING SYSTEM (GPS) EQUIPMENT AND OPERATIONS.**

*A. Portable Units.* Portable GPS receivers can only be used as a supplemental aid to VFR in conjunction with an approved primary means of navigation. All portable electronic systems and portable GPS units must be handled in accordance with the provisions of 14 CFR part 91, § 91.21. The operator of the aircraft must determine that each portable electronic device will not cause interference with the navigation and communications systems of the aircraft on which it is to be used. Yoke mounts usually sold with a portable GPS unit must be mounted as to not interfere with the operation of the aircraft controls. Permanent mounts and externally mounted antennas for use with a portable GPS unit must be installed in an FAA-approved manner. A critical aspect of any GPS installation is the installation of the antenna. Shadowing by the aircraft structure can adversely affect the operation of the GPS equipment. Operators should be aware that a GPS signal is weak, typically below the value of the background noise. Electrical noise or static in the vicinity of the antenna can adversely affect the performance of the system.

*B. GPS Equipment Classes.* GPS equipment is categorized into classes A( ), B( ), and C( ) (refer to TSO-C129, TSO-C145, and TSO-C146). See figure 4.1.2.1.

(1) *Class A( ).* Equipment incorporating both the GPS sensor and navigation capability. This equipment incorporates Receiver Autonomous Integrity Monitoring (RAIM). See subparagraph E for more discussion in regard to RAIM.

(a) Class A1 equipment includes en route, terminal, and nonprecision approach navigation capability.

(b) Class A2 equipment includes only en route and terminal navigation capability.

(2) *Class B()*. Equipment consisting of a GPS sensor that provides data to an integrated navigation system (i.e., Flight Management System (FMS), multi-sensor navigation system, etc.).

(a) Class B1 equipment includes RAIM and provides en route, terminal, and nonprecision approach capability.

(b) Class B2 equipment includes RAIM and provides only en route and terminal capability.

(c) Class B3 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route, terminal, and nonprecision approach capability.

(d) Class B4 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides only en route and terminal capability.

(3) *Class C()*. Equipment consisting of a GPS sensor that provides data to an integrated navigation system (i.e., FMS, multisensor navigation system, etc.) that provides enhanced guidance to an autopilot or flight director in order to reduce flight technical error.

(a) Class C1 equipment includes RAIM and provides en route, terminal, and nonprecision approach capability.

(b) Class C2 equipment includes RAIM and provides only en route and terminal capability.

(c) Class C3 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route, terminal, and nonprecision approach capability.

(d) Class C4 equipment requires the integrated navigation system to provide a level of GPS integrity

equivalent to RAIM and provides only en route and terminal capability.

*C. Avionics-Initial Installations and Continued Airworthiness.* The operator must assure that the equipment is properly installed and maintained. No special maintenance requirements, other than the standard practices currently applicable to navigation or landing systems, have been identified that are unique to GPS (e.g., Airworthiness Directives, Service Bulletins.)

(1) Documentation must be provided that validates approval of the installed GPS airborne receiver in accordance with Notice N8110.60, AC 20-129 (as amended), Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. NAS and Alaska, and AC 20-130 (as amended), as appropriate, or other applicable airworthiness criteria established for GPS installations. When it has been established that the airborne system has been certified for GPS IFR operations, the following criteria should be used to determine the operational suitability of airborne systems for GPS IFR use.

(2) A GPS installation with a TSO C-129 (or TSO C-145a or TSO C-146a, as applicable) authorized navigation system in Class A1, A2, B1, B2, C1, or C2 may be used in combination with other approved long-range navigation systems (LRNS) for unrestricted operations in NAT MNPS airspace or may be used as the primary means of long-range navigation on the special routes that have been developed for aircraft equipped with only one LRNS and on the special routes developed for aircraft equipped with short-range navigation equipment. The basic integrity for these operations must be provided by RAIM or an equivalent method. A single GPS installation in Class A1, A2, B1, B2, C1, or C2, which provides RAIM for integrity monitoring, may also be used on those short oceanic routes that have only one required means of long-range navigation.

| FIGURE 4.1.2.1 GPS EQUIPMENT CLASSES   |                                |  |              |              |              |                               |
|--|--------------------------------|--|--------------|--------------|--------------|-------------------------------|
| TSO-C129   |                                |  |              |              |              |                               |
| EQUIPMENT CLASS  | RAIM                           | Integrated Navigation System to Provide RAIM Equivalent. | OCEANIC      | EN ROUTE     | TERMINAL     | NONPRECISION APPROACH CAPABLE |
| Class A - GPS sensor and navigation capability   |                                |  |              |              |              |                               |
| A1   | Yes                            |  | Yes          | Yes          | Yes          | Yes                           |
| A2   | Yes                            |  | Yes          | Yes          | Yes          | No                            |
| Class B - GPS sensor data to an integrated navigation system (i.e., FMS, multi-sensor navigation system, etc.)   |                                |  |              |              |              |                               |
| B1   | Yes                            |  | Yes          | Yes          | Yes          | Yes                           |
| B2   | Yes                            |  | Yes          | Yes          | Yes          | No                            |
| B3   |                                | Yes  | Yes          | Yes          | Yes          | Yes                           |
| B4   |                                | Yes  | Yes          | Yes          | Yes          | No                            |
| Class C - GPS sensor data to an integrated navigation system (as in Class B) that provides enhanced guidance to an autopilot or flight director to reduce flight technical errors. Limited to part 121 or equivalent criteria. |                                |  |              |              |              |                               |
| C1   | Yes                            |  | Yes          | Yes          | Yes          | Yes                           |
| C2   | Yes                            |  | Yes          | Yes          | Yes          | No                            |
| C3   |                                | Yes  | Yes          | yes          | Yes          | Yes                           |
| C4   | Yes                            | Yes  | Yes          | yes          | No           |                               |
| GPS Approval Required For Authorized Use   |                                |  |              |              |              |                               |
| EQUIPMENT TYPE   | INSTALLATION APPROVAL REQUIRED | OPERATIONAL APPROVAL REQUIRED                            | IFR EN ROUTE | IFR TERMINAL | IFR APPROACH |                               |
| Hand Held  | X                              |  |              |              |              |                               |
| VFR Panel Mount  | X                              |  |              |              |              |                               |
| IFR En Route and Terminal  | X                              | X  | X            | X            | X            |                               |
| IFR Oceanic/Remote   | X                              | X  | X            | X            |              |                               |
| IFR En Route, Terminal, and Approach   | X                              | X  | X            | X            | X            |                               |

*D. GPS Equipment Approval and Installation for Class II Navigation and Remote Areas.* The approval of GPS to provide the primary means of Class II navigation requires equipment approval, installation approval, and operational approval. Primary Means of navigation equipment is that which provides the only required means on the aircraft of satisfying the necessary levels of accuracy, integrity, and availability for a particular area, route, procedure, or operation.

(1) *GPS Equipment Approval.* In addition to specific aircraft certification requirements, as outlined in FAA Notice N8110.60 (as amended), GPS as a Primary Means of Navigation for Oceanic/Remote Operations, dual long-range GPS receivers are required for GPS (TSO C-129) to be approved as a primary means of navigation in oceanic airspace. The equipment must be approved by the FAA Aircraft Certification Service (AIR) in accordance with:

- AC 20-138 (as amended) or AC 20-130 (as amended)
- Notice N 8110.60

(2) *Installation.* The applicant must obtain initial installation approval of GPS equipment for primary use on a specific make and model aircraft via the TC or STC certification process. FAA Form 337 or forms acceptable to the Administrator for those operators with acceptable engineering organization will be used for the installation of the same GPS equipment in the same make/model aircraft provided the data developed for the initial certification is used. (For more information, see Order 8300.10, Airworthiness Inspector's Handbook.)

(3) *Aircraft Flight Manual Supplement (AFMS).* Once the installation has been approved, the AFMS must be updated to state: "The \_\_\_\_ GPS equipment as installed has been found to comply with the requirements for GPS primary means of Class II navigation in oceanic and remote airspace, when used in conjunction with the \_\_\_\_ prediction program. This does not constitute operational approval." Detailed requirements for AFMS content are contained in FAA Notice N8110.60.

*E. System Availability.*

(1) *Receiver Autonomous Integrity Monitoring*

(*RAIM*). RAIM is a technique whereby a civil GPS receiver/processor determines the integrity of the GPS navigation signals using only GPS signals or GPS signals augmented with altitude. This determination is achieved by a consistency check among a series of satellites being tracked. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function.

(2) *Fault Detection Exclusion (FDE) Availability Prediction Program*. FDE is the capability of GPS to detect a satellite failure that effects navigation and automatically exclude that satellite from the navigation solution. All operators conducting GPS primary means of Class II navigation in oceanic/remote areas under parts 91, 121, 125, and 135 must utilize an FAA-approved FDE prediction program for the installed GPS equipment that is capable of predicting, prior to departure, the maximum outage duration of the loss of fault exclusion, the loss of fault detection, and the loss of navigation function for flight on a specified route. The "specified route of flight" is defined by a series of waypoints (to include the route to any required alternates) with the time specified by a velocity or series of velocities. Since specific ground speeds may not be maintained, the pre-departure prediction must be performed for the range of expected ground speeds. This FDE prediction program must use the same FDE algorithm (a step-by-step procedure for solving a problem) that is employed by the installed GPS equipment and must be developed using an acceptable software development methodology. The FDE prediction program must provide the capability to manually designate satellites that are scheduled to be unavailable in order to perform the prediction accurately. The FDE prediction program will be evaluated as part of the navigation system's installation approval. The requirements for the FDE prediction algorithm can be found in FAA Notice N8110.60 or its successor.

(3) *Operational Control Restrictions for Class II navigation in oceanic and remote areas*.

(a) Prior to departure, the operator must use the FDE prediction program to demonstrate that there are no outages in the capability to navigate the specified route of flight (the FDE prediction program determines whether the GPS constellation is robust enough to provide a navigation solution for the specified route of flight). Any predicted satellite outages that affect the capability of GPS equipment to provide the navigation function on the specified route of flight requires that the flight be canceled, delayed, or re-routed.

(b) Once navigation function is assured (the equipment can navigate on the specified route of flight), the operator must use the FDE prediction program to demonstrate that the maximum outage of the capability of the equipment to provide fault exclusion for the specified route of flight does not exceed the acceptable duration (fault exclusion is the ability to exclude a failed satellite from the

navigation solution). The acceptable duration (in minutes) is equal to the time it would take to exit the protected airspace (one-half the lateral separation minimum), assuming a 35 nautical mile per hour cross-track navigation system error growth rate when starting from the center of the route. For example, a 60 nautical mile lateral separation minimum yields 51 minutes acceptable duration (30 nautical miles divided by 35 nautical miles per hour). If the fault exclusion outage exceeds the acceptable duration, the flight must be canceled, delayed, or re-routed. If the fault exclusion capability outage (exclusion of a malfunctioning satellite) exceeds the acceptable duration on the specific route of flight, the flight must be canceled, delayed, or re-routed.

*F. En Route Procedures for GPS Class II Navigation in Oceanic and Remote Areas.*

(1) *Degraded Navigation Capability*. If the GPS displays a loss of navigation function alert, the pilot should maintain heading and altitude until GPS navigation is regained. The pilot will report degraded navigation capability to ATC in accordance with part 91, section 91.187. Additionally, flightcrew members operating under 14 CFR part 121 will notify the appropriate dispatch or flight following facility of any degraded navigation capability in accordance with the air carrier's FAA-approved procedures. For at least one hour, the approved long-range GPS units have the ability to automatically provide electronic dead reckoning navigation solutions based on last known information. There are strict procedural requirements for dispatch and en route RAIM to ensure satellite coverage along the oceanic routes and that no outages are scheduled to occur during the planned flight. The standardized application of disciplined, systematic cross-checking of navigation information during all phases of flight during Class II navigation should be required in each operator's long-range navigation program. AC 91-70, as amended, Oceanic Operations, provides amplification of these procedures.

(2) *Satellite Fault Detection Outage*. If the GPS displays an indication that a fault detection function outage (e.g., RAIM) is not available, navigation integrity must be provided by comparing the GPS position with a position computed by extrapolating the last verified position with true airspeed, heading, and estimated winds. If the positions do not agree to within 10 nautical miles, the pilot should immediately maintain heading and altitude until the exclusion function or navigation integrity is regained and report degraded navigation capability to ATC in accordance with § 91.187.

(3) *Fault Detection Alert*. If the GPS displays a fault detection alert (failed satellite), the pilot may choose to continue to operate using the GPS-generated position if the current estimate of position uncertainty displayed on the GPS from the FDE algorithm is actively monitored. If this number exceeds 10 nautical miles or is not available, the pilot should immediately maintain heading and altitude until

the failed satellite is excluded and report degraded navigation capability to ATC in accordance with section 91.187.

(4) *Validation Tests are Required.* Such tests may consist of a single flight or series of flights. The following references are provided:

- Part 121, section 121.93
- Part 121, section 121.113
- Part 135, section 135.13(a)(2)
- FAA Order 8400.10, Volume 3, Chapter 9, Section 8, and Volume 4, Chapter 1, Section 2.

G. An approved GPS navigation system may be substituted for both an Automatic Direction Finder (ADF) and DME receiver, provided facility or fix coordinates can be called up from the current GPS airborne database. Waypoints, fixes, intersections, and facility locations used for these operations must be retrieved from the current GPS airborne database. If the required positions cannot be retrieved from the airborne database, the substitution of GPS for ADF and DME is not authorized.

(1) For all operators, using GPS in lieu of DME does not preclude any equipment requirements of the applicable regulations. To provide navigation performance equivalent to ADF or DME avionics, the GPS navigation systems must be properly certified, installed, and authorized for use under IFR, as described above.

(2) This approval does not alter the conditions and requirements for use of GPS when GPS is used to provide lateral course guidance to fly GPS or GPS RNAV standard instrument approach procedures.

(3) For those operations where the operating rules require that DME be installed, the operator's MEL should include provisions for authorizing continued operations using a certified GPS when the installed DME is inoperative. Operators in the NAS may be authorized to use GPS equipment certified for IFR operations in lieu of ADF and DME equipment for the following operations:

- (a) *Determining the aircraft position over a DME fix.* GPS satisfies the part 91, section 91.205e requirement for DME at and above 24,000 feet MSL (FL240).
- (b) Flying a DME arc.
- (c) Navigating to/from an NDB/compass locator.
- (d) Determining the aircraft position over an NDB/compass locator.
- (e) Determining the aircraft position over a fix made up of a crossing NDB/compass locator bearing.
- (f) Holding over an NDB/compass locator.
- (g) The ground-based NDB or DME facility may be temporarily out of service.

(4) For further information on the use of GPS in lieu of DME, refer to the Aeronautical Information Manual (AIM).

## 52. FAA APPROVAL OF GPS/WIDE AREA AUGMENTATION NAVIGATION SYSTEMS (WAAS).

A. *General.* GPS/Wide Area Augmentation System (WAAS)-capable navigation systems are approved under Technical Standards Order (TSO)-C145a or TSO-C146a.

(1) TSO-145a applies to GPS/WAAS sensors incorporated as a component of a Flight Management System (FMS).

(2) TSO-146a applies to stand-alone GPS/WAAS units.

(3) This GPS/WAAS equipment constitutes a significant improvement over the older GPS (non-WAAS) standards provided by TSO-C129 equipment with technology that provides:

(a) Enhanced signal integrity using GPS/WAAS, Fault Detection and Exclusion (FDE), and Receiver Autonomous Integrity Monitoring (RAIM).

(b) Improved navigation accuracy, availability, and flexibility that will ultimately produce an increase in both system capacity and overall flight safety.

(c) Performance capabilities for new IFR RNAV routes that are currently under development for navigation in domestic and remote airspace.

(d) Performance accuracy to meet Required Navigation Performance (RNP)-2, RNP-1, and RNP-0.3; and the equivalent containment values in Figure 4.1.2.3 below.

B. *GPS/WAAS Equipment.* Figure 4.1.2.2, GPS/WAAS Equipment Classes, should be used to authorize the phase of flight (modes) and intended operational use when approving GPS/WAAS navigation systems.

(1) TSO-C145a provides the certification standards for airborne navigation GPS/WAAS sensors, as part of a FMS, that is categorized into three classes.

(2) TSO-C146a GPS/WAAS equipment refers to a GPS/WAAS stand-alone airborne navigation system that is categorized into four classes.

(3) TSO-C145a/C146a equipment must be installed in accordance with Advisory Circular (AC) 20-138, Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment, as amended.

(4) For TSO-C145a GPS/WAAS sensors, the parent FMS must comply with TSO-C115b (installed in accordance with AC 20-130, Airworthiness Approval of Naviga-



tion or Flight Management Systems Integrating Multiple Navigation Sensors, as amended).

| <b>FIGURE 4.1.2.2. GPS/WAAS EQUIPMENT CLASSES</b>    |   |                             |  |
|--|---|-----------------------------|--|
| <b>For TSO-C145a Sensors and TSO-C146a Receivers</b> |   |                             |  |
| <b>Equipment Class</b>                               | <b>Oceanic and Domestic En Route, Terminal Area Operations, Nonprecision Approach</b> | <b>LNAV/VNAV Approaches</b> | <b>Lateral Path Vertical Guidance (LPV) Approaches</b> |
| <b>GPS/WAAS Sensor [TSO-C145a]</b>                   |   |                             |  |
| Class 1  | Yes   | No                          | No   |
| Class 2  | Yes   | Yes                         | No   |
| Class 3  | Yes   | Yes                         | Yes  |
| <b>GPS/WAAS Navigation Equipment [TSO-C146a]</b>     |   |                             |  |
| Class 1  | Yes   | No                          | No   |
| Class 2  | Yes   | Yes                         | No   |
| Class 3  | Yes   | Yes                         | Yes  |
| Class 4  | No  | No                          | Yes  |

*C. IFR Operations in the NAS.* GPS/WAAS equipment meets the performance accuracy for operations over all existing published or approved air traffic service routes including air traffic clearances “direct to” fixes or navigation aids. These routes, navaids, or fixes must be retrievable from the navigation database. When all applicable provisions outlined in paragraphs #51 and #52 are met, including the installation of dual independent systems appropriate to the route of flight, GPS/WAAS equipment may be authorized for use as the only means of navigation in conducting IFR navigation in the U.S. NAS. This requirement may be met with:

(1) Dual Class 1, 2, or 3 (see subparagraph B and figure 4.1.2.2 above) GPS/WAAS TSO-C146a units; or

(2) Dual independent flight management systems (FMS) that comply with TSO-C115b (installed in accordance with AC 20-130, as amended) with dual TSO-C145a, Class 1, 2 or 3 sensors (installed in accordance with AC 20-138, as amended), or

(3) A combination of one GPS/WAAS TSO-C146a unit and one FMS with a GPS/WAAS TSO-C145a sensor.

**NOTE: The FAA has certified GPS/WAAS systems as primary navigation systems and they can be used as the only means of navigation as long as the 14 CFR operating rules do not prohibit this use. Whereas, GPS navigation systems certified under**

**TSO-C129 are limited as a supplemental means of navigation except for certain operation in oceanic and remote areas when TSO-C129 systems meet FAA Notice 8110.60.**

*D. GPS/WAAS, TSO-C145a, or TSO-C146a (and subsequent revisions) Equipment Can be Approved For Operations Where an Accuracy Performance of RNP -2, -1, or -0.3 is Required.*

(1) GPS/WAAS systems certified under TSO-C145a or TSO-C146a and installed in accordance with AC 20-138, as amended, performs to the accuracy requirements of RNP-2, RNP-1, or RNP-0.3; and the equivalent containment values in Figure 4.1.2.3 below.

(2) A flight management system with a TSO-C145a sensor, and TSO-C146a units with documentation in the AFM or AFMS of the RNP types for the installed GPS/WAAS navigation system of RNP-2, -1, and -0.3 can be authorized for operations requiring those RNP types.

(3) TSO-C145a and TSO-C146a GPS/WAAS equipment meets the performance requirements for operations over all existing published air traffic service routes and “direct to” routes authorized in an air traffic clearance. Navigation databases used in conjunction with these routes must be current and include the applicable published procedures.

**Figure 4.1.2.3. RNP types or RNAV containment values used in association with this approval under paragraph 52.**

| <b>RNP Type</b> | <b>Required Accuracy<br/>(95% Containment)</b> | <b>Description</b>   |
|-----------------|--|--|
| 0.3             | ± 0.3 NM                                       | Non-precision, LNAV, VNAV, and some LPV approaches using GPS/WAAS.                         |
| 1               | ± 1.0 NM                                       | Supports Arrival, Initial/Intermediate Approach, Departure and some En route applications. |
| 2               | ± 2.0 NM                                       | Supports ATS routes and airspace.  |

(4) TSO-145a and TSO-C146a equipment without an RNP statement in the AFM or Aircraft Flight Manual Supplement (AFMS), performs to the accuracy requirements of RNP-2, RNP-1, and RNP-0.3 when in en route mode, terminal mode, or non-precision approach modes respectively and the installed equipment provides annunciation to the pilot of the mode that is in use. If the TSO-C146a equipment meets this requirement it can be authorized for operations requiring those RNP types.

(5) Operational approvals may be issued to authorize an operator to conduct approved or published en route, terminal, and approach procedures that require these specific RNP values if they meet the following general requirements. (This authorization could apply to any published or special en route, terminal, or approach procedure).

(a) The approved GPS/WAAS system must be installed and operating when conducting flights over the published or approved route segments or procedures.

(b) Operators approved for en route segments using these RNP types should include modules in their training program that ensure the pilot's ability to accurately maintain the aircraft's position within the protected portions of the route or procedure using reduced Course Deviation Indicator (CDI) guidance cues.

(6) Questions concerning the operational approval for en route, terminal, or approach procedures requiring a published RNP should be directed to the appropriate FAA Regional All Weather Office (AWO) or AFS-400.

*E. Operational Approval for Operations in Alaska.* For operations in Alaska, see Order 8400.10, volume 4, chapter 1, section 1, paragraph 5D(4), and SFAR 97, Special operating rules for the conduct of Instrument Flight rules (IFR) Area Navigation (RNAV) operations using Global Positioning Systems (GPS) in Alaska.

(1) OpSpec B030 is issued to those certificate holders and operators identified in Section 1 of SFAR 97 for IFR RNAV en route operations in the State of Alaska and its airspace on published air traffic routes using navigation systems, certified in accordance with TSO-C145a/C146a, as the only means of IFR navigation appropriate for the route to be flown.

(2) Additional guidance for this authorization is outlined in Order 8400.10, volume 3, chapter 1, section 4, part B, OPSPEC B030 – IFR Navigation Using GPS/WAAS RNAV Systems.

**53-70 RESERVED.**

**[PAGES 4-33 THROUGH 4-34 RESERVED]**